

CHAPTER 3 [CE]

GENERAL REQUIREMENTS

SECTION R301 CLIMATE ZONES

C301.1 General. Climate zones from Table C301.1 shall be used in determining the applicable requirements from Chapter 4.



**TABLE C301.1
CLIMATE ZONES, MOISTURE REGIMES,
AND WARM-HUMID DESIGNATIONS
BY STATE AND COUNTY**

Key: A - Moist, B - Dry, C - Marine.
Absence of moisture designation indicates
moisture regime is irrelevant.

WASHINGTON

5B Adams	4C Lewis
5B Asotin	5B Lincoln
5B Benton	4C Mason
5B Chelan	<u>5B</u> Okanogan
4C Clallam	4C Pacific
4C Clark	<u>5B</u> Pend Oreille
5B Columbia	4C Pierce
4C Cowlitz	4C San Juan
5B Douglas	4C Skagit
<u>5B</u> Ferry	5B Skamania
5B Franklin	4C Snohomish
5B Garfield	5B Spokane
5B Grant	<u>5B</u> Stevens
4C Grays Harbor	4C Thurston
4C Island	4C Wahkiakum
4C Jefferson	5B Walla Walla
4C King	4C Whatcom
4C Kitsap	5B Whitman
5B Kittitas	5B Yakima
5B Klickitat	

SECTION C302 DESIGN CONDITIONS

C302.1 Interior design conditions. The interior design temperatures used for heating and cooling load calculations shall be a maximum of 72°F (22°C) for heating and minimum of 75°F (24°C) for cooling.

C302.2 Exterior design conditions. The heating or cooling outdoor design temperatures shall be selected from Appendix C.

SECTION C303 MATERIALS, SYSTEMS AND EQUIPMENT

C303.1 Identification. Materials, systems and equipment shall be identified in a manner that will allow a determination of compliance with the applicable provisions of this code.

C303.1.1 Building thermal envelope insulation. An *R*-value identification mark shall be applied by the manufacturer to each piece of *building thermal envelope* insulation 12 inches (305 mm) or greater in width. Alternately, the insulation installers shall provide a certification listing the type, manufacturer and *R*-value of insulation installed in each element of the *building thermal envelope*. For blown or sprayed insulation (fiberglass and cellulose), the initial installed thickness, settled thickness, settled *R*-value, installed density, coverage area and number of bags installed shall be *listed* on the certification. For sprayed polyurethane foam (SPF) insulation, the installed thickness of the areas covered and *R*-value of installed thickness shall be *listed* on the certification. The insulation installer shall sign, date and post the certification in a conspicuous location on the job site.

C303.1.1.1 Blown or sprayed roof/ceiling insulation. The thickness of blown-in or sprayed roof/ceiling insulation (fiberglass or cellulose) shall be written in inches (mm) on markers that are installed at least one for every 300 square feet (28 m²) throughout the attic space. The markers shall be affixed to the trusses or joists and marked with the minimum initial installed thickness with numbers a minimum of 1 inch (25 mm) in height.

Replaces Page CE-19

Each marker shall face the attic access opening. Spray polyurethane foam thickness and installed *R*-value shall be *listed* on certification provided by the insulation installer.

C303.1.2 Insulation mark installation. Insulating materials shall be installed such that the manufacturer's *R*-value mark is readily observable upon inspection.

C303.1.3 Fenestration product rating. *U*-factors of fenestration products (windows, doors and skylights) shall be determined in accordance with NFRC 100 by an accredited, independent laboratory, and labeled and certified by the manufacturer. Products lacking such a labeled *U*-factor shall be assigned a default *U*-factor from Table C303.1.3(1), C303.1.3(2) or C303.1.3(4). The solar heat gain coefficient (SHGC) and visible transmittance (VT) of glazed fenestration products (windows, glazed doors and skylights) shall be determined in accordance with NFRC 200 by an accredited, independent laboratory, and labeled and certified by the manufacturer. Products lacking such a labeled SHGC or VT shall be assigned a default SHGC or VT from Table C303.1.3(3).

Exception: Units without NFRC ratings produced by a *small business* may be assigned default *U*-factors from Table C303.1.3(5) for vertical fenestration.

**TABLE C303.1.3(1)
DEFAULT GLAZED FENESTRATION U-FACTOR**

FRAME TYPE	SINGLE PANE	DOUBLE PANE	SKYLIGHT
Metal	1.20	0.80	See Table C303.1.3(4)
Metal with Thermal Break ¹	1.10	0.65	
Nonmetal or Metal Clad	0.95	0.55	
Glazed Block	0.60		

¹ Metal Thermal Break = A metal thermal break framed window shall incorporate the following minimum design characteristics:

- a) The thermal conductivity of the thermal break material shall be not more than 3.6 Btu-in/h/ft²/°F;
- b) The thermal break material must produce a gap in the frame material of not less than 0.210 inches; and
- c) All metal framing members of the products exposed to interior and exterior air shall incorporate a thermal break meeting the criteria in a) and b) above.

C303.1.4 Insulation product rating. The thermal resistance (*R*-value) of insulation shall be determined in accordance with the U.S. Federal Trade Commission *R*-value rule (C.F.R. Title 16, Part 460) in units of h × ft² × °F/Btu at a mean temperature of 75°F (24°C).

C303.2 Installation. All materials, systems and equipment shall be installed in accordance with the manufacturer's installation instructions and the *International Building Code* or *International Residential Code*, as applicable.

C303.2.1 Protection of exposed foundation insulation. Insulation applied to the exterior of basement walls, crawlspace walls and the perimeter of slab-on-grade floors shall have a rigid, opaque and weather-resistant protective covering to prevent the degradation of the insulation's thermal performance. The protective covering shall cover the exposed exterior insulation and extend a minimum of 6 inches (153 mm) below grade.

C303.3 Maintenance information. Maintenance instructions shall be furnished for equipment and systems that require preventive maintenance. Required regular maintenance actions shall be clearly stated and incorporated on a *readily accessible* label. The label shall include the title or publication number for the operation and maintenance manual for that particular model and type of product.

**TABLE C303.1.3(2)
DEFAULT DOOR U-FACTORS**

See Appendix A, Section A107

**TABLE C303.1.3(3)
DEFAULT GLAZED FENESTRATION
SHGC AND VT**

	SINGLE GLAZED		DOUBLE GLAZED		GLAZED BLOCK
	Clear	Tinted	Clear	Tinted	
SHGC	0.40	0.40	0.40	0.40	0.40
VT	0.6	0.3	0.6	0.3	0.6

C402.1.3.2 Component U -factors. The U -factors for typical construction assemblies are included in Chapter 3 and Appendix A. These values shall be used for all calculations. Where proposed construction assemblies are not represented in Chapter 3 or Appendix A, values shall be calculated in accordance with the ASHRAE Handbook - Fundamentals, using the framing factors listed in Appendix A.

For envelope assemblies containing metal framing, the U -factor shall be determined by one of the following methods:

1. Results of laboratory measurements according to acceptable methods of test.
2. ASHRAE Handbook - Fundamentals where the metal framing is bonded on one or both sides to a metal skin or covering.
3. The zone method as provided in ASHRAE Handbook - Fundamentals.
4. Effective framing/cavity R -values as provided in Appendix A. When return air ceiling plenums are employed, the roof/ceiling assembly shall:
 - a. For thermal transmittance purposes, not include the ceiling proper nor the plenum space as part of the assembly; and
 - b. For gross area purposes, be based upon the interior face of the upper plenum surface.
5. Tables in ASHRAE 90.1-2010 Normative Appendix A.

C402.1.3.3 UA calculations. The target UA_t and the proposed UA_p shall be calculated using Equations C402-1 and C402-2 and the corresponding areas and U -factors from Table C402.1.2 and Table C402.3. For the target UA_t calculation, the skylights shall be located in roof/ceiling area up to the maximum skylight area per Section C402.3.1 and the remainder of the fenestration allowed per Section C402.3.1 shall be located in the wall area.

C402.1.3.4 SHGC rate calculations. Solar heat gain coefficient shall comply with Table C402.3. The target $SHGCA_t$ and the proposed $SHGCA_p$ shall be calculated using Equations C402-3 and C402-4 and the corresponding areas and SHGCs from Table C402.3.

C402.1.4 Semi-heated spaces. All spaces shall comply with the requirements in Section C402 unless they meet the definition for semi-heated spaces. For semi-heated spaces, the building envelope shall comply with the same requirements as that for conditioned spaces in Section C402; however, for semi-heated spaces heated by other than electric resistance heating equipment, wall insulation is not required for those walls that separate semi-heated spaces from the exterior provided that the space meets all the requirements of semi-heated space. Semi-heated spaces shall be calculated separately from other conditioned spaces for compliance purposes. Building envelope assemblies separating conditioned space from semi-heated space shall comply with exterior envelope insulation requirements. When choosing the uninsulated wall option, the wall shall not be included in Component Performance Building Envelope Option calculation.

C402.2 Specific insulation requirements

(Prescriptive). Opaque assemblies shall comply with Table C402.2. Where two or more layers of continuous insulation board are used in a construction assembly, the continuous insulation boards shall be installed in accordance with Section C303.2. If the continuous insulation board manufacturer's installation instructions do not address installation of two or more layers, the edge joints between each layer of continuous insulation boards shall be staggered.

**EQUATION C402-1
TARGET UA_T**

$$UA_t = U_{\text{radt}}A_{\text{radt}} + U_{\text{mrt}}A_{\text{mrt}} + U_{\text{rat}}A_{\text{rat}} + U_{\text{mwt}}(A_{\text{mwt}} + A_{\text{mwbgt}}) + U_{\text{mbwt}}(A_{\text{mbwt}} + A_{\text{mbwbgt}}) + U_{\text{sfwt}}(A_{\text{sfwt}} + A_{\text{sfwbgt}}) + U_{\text{wfwtd}}(A_{\text{wfwtd}} + A_{\text{wfwbgt}}) + U_{\text{fnt}}A_{\text{fnt}} + U_{\text{fjt}}A_{\text{fjt}} + F_{\text{st}}P_{\text{st}} + F_{\text{srt}}P_{\text{srt}} + U_{\text{dst}}A_{\text{dst}} + U_{\text{drt}}A_{\text{drt}} + U_{\text{vgt}}A_{\text{vgt}} + U_{\text{vgmt}}A_{\text{vgmt}} + U_{\text{vgmot}}A_{\text{vgmot}} + U_{\text{vgdt}}A_{\text{vgdt}} + U_{\text{ogt}}A_{\text{ogt}}$$

U_{at} = The target combined specific heat transfer of the gross roof/ceiling assembly, exterior wall and floor area.

Where:

U_{radt} = The thermal transmittance value for roofs with the insulation entirely above deck found in Table C402.1.2.

U_{mrt} = The thermal transmittance value for metal building roofs found in Table C402.1.2.

U_{rat} = The thermal transmittance value for attic and other roofs found in Table C402.1.2.

U_{mwt} = The thermal transmittance value for opaque mass walls found in Table C402.1.2.

U_{mbwt} = The thermal transmittance value for opaque metal building walls found in Table C402.1.2.

U_{sfwt} = The thermal transmittance value for opaque steel-framed walls found in Table C402.1.2.

U_{wfwtd} = The thermal transmittance value for opaque wood framed and other walls found in Table C402.1.2.

U_{fnt} = The thermal transmittance value for mass floors over unconditioned space found in Table C402.1.2.

U_{fjt} = The thermal transmittance value for joist floors over unconditioned space found in Table C402.1.2.

F_{st} = The F-factor for slab-on-grade floors found in Table C402.1.2.

F_{srt} = The F-factor for radiant slab floors found in Table C402.1.2.

U_{dst} = The thermal transmittance value for opaque swinging doors found in Table C402.2.

U_{drt} = The thermal transmittance value for opaque roll-up or sliding doors found in Table C402.2.

U_{vgt} = The thermal transmittance value for vertical fenestration with nonmetal framing found in Table C402.3 which corresponds to the proposed vertical fenestration area as a percent of gross exterior wall area.* Buildings utilizing Section C402.3.1.3 shall use the thermal transmittance value specified there.

U_{vgmt} = The thermal transmittance value for vertical fenestration with fixed metal framing found in Table C402.3 which corresponds to the proposed vertical fenestration area as a percent of gross exterior wall area.* Buildings utilizing Section C402.3.1.3 shall use the thermal transmittance value specified there.

U_{vgmot} = The thermal transmittance value for vertical fenestration with operable metal framing found in Table C402.3 which corresponds to the proposed vertical fenestration area as a percent of gross exterior wall area.* Buildings utilizing Section C402.3.1.3 shall use the thermal transmittance value specified there.

U_{vgdt} = The thermal transmittance value for entrance doors found in Table C402.3 which corresponds to the proposed vertical fenestration area as a percent of gross exterior wall area.* Buildings utilizing Section C402.3.1.3 shall use the thermal transmittance value specified there.

U_{ogt} = The thermal transmittance for skylights found in Table C402.3 which corresponds to the proposed skylight area as a percent of gross exterior roof area.

A_{fnt} = The proposed mass floor over unconditioned space area, A_{fm} .

Replaces Page CE-26

- A_{jt} = The proposed joist floor over unconditioned space area, A_{jt} .
 - P_{st} = The proposed linear feet of slab-on-grade floor perimeter, P_s .
 - P_{srt} = The proposed linear feet of radiant slab floor perimeter, P_{rs} .
 - A_{dst} = The proposed opaque swinging door area, A_{ds} .
 - A_{drt} = The proposed opaque roll-up or sliding door area, A_{dr} .
- and

If the vertical fenestration area as a percent of gross exterior above-grade wall area does not exceed the maximum allowed in Section C402.3.1.3:

- A_{mwt} = The proposed opaque above grade mass wall area, A_{mw} .
 - A_{mwbgt} = The proposed opaque below grade mass wall area, A_{mwbgt} .
 - A_{mbwt} = The proposed opaque above grade metal building wall area, A_{mbw} .
 - A_{mbwbgt} = The proposed opaque below grade metal building wall area, A_{mbwbgt} .
 - A_{sftwt} = The proposed opaque above grade steel framed wall area, A_{mfw} .
 - A_{sfwbgt} = The proposed opaque below grade steel framed wall area, A_{mfwbgt} .
 - A_{wftwt} = The proposed opaque above grade wall wood framed and other area, A_{wfw} .
 - A_{wfwbgt} = The proposed opaque below grade wall wood framed and other area, A_{wfwbgt} .
 - A_{vgt} = The proposed vertical fenestration area with nonmetal framing, A_{vg} .
 - A_{vgmt} = The proposed vertical fenestration area with fixed metal framing, A_{vgm} .
 - A_{vgmot} = The proposed vertical fenestration area with operable metal framing, A_{vgmo} .
 - A_{vgdt} = The proposed entrance door area, A_{vgd} .
- or

For buildings utilizing Section C402.3.1.3, vertical fenestration area as a percent of gross exterior above-grade wall may not exceed the amount allowed by that section. For all other buildings, if the vertical fenestration area as a percent of gross exterior above-grade wall area exceeds the maximum allowed in Section C402.3.1, the area of each vertical fenestration element shall be reduced in the base envelope design by the same percentage and the net area of each above-grade wall type increased proportionately by the same percentage so that the total vertical fenestration area is exactly equal to the allowed percentage per Section C402.3.1 of the gross above-grade wall area. The target wall area of a given wall type shall be the sum of the proposed below-grade area and the increased above-grade area.

and

If the skylight area as a percent of gross exterior roof area does not exceed the maximum allowed in Section C402.3.1:

- A_{radt} = The proposed roof area with insulation entirely above the deck, A_{rad} .
- A_{mrt} = The proposed roof area for metal buildings, A_{mr} .
- A_{rat} = The proposed attic and other roof area, A_{or} .
- A_{ogat} = The proposed skylight area, A_{ogor} .

or

If the skylight area as a percent of gross exterior roof area exceeds the maximum allowed in Section C402.3.1, the area of each skylight element shall be reduced in the base envelope design by the same percentage and the net area of each roof type increased proportionately by the same percentage so that the total skylight area is exactly equal to the allowed percentage per Section C402.3.1 of the gross roof area.

***NOTE:** The vertical fenestration area does not include opaque doors and opaque spandrel panels.

**EQUATION C402-2
PROPOSED UA_p**

$$UA_p = U_{rad}A_{rad} + U_{mr}A_{mr} + U_{ra}A_{ra} + U_{mw}A_{mw} + U_{mbw}A_{mbw} + U_{sfw}A_{sfw} + U_{wfw}A_{wfw} + U_{fm}A_{fm} + U_{fj}A_{fj} + F_sP_s + F_{sr}P_{sr} + U_{ds}A_{ds} + U_{dr}A_{dr} + U_{vg}A_{vg} + U_{vgmf}A_{vgmf} + U_{vgmo}A_{vgmo} + U_{vgd}A_{vgd} + U_{og}A_{og}$$

Where:

- UA_p = The combined proposed specific heat transfer of the gross exterior wall, floor and roof/ceiling assembly area.
- U_{rad} = The thermal transmittance of the roof area where the insulation is entirely above the roof deck.
- A_{rad} = Opaque roof area where the insulation is entirely above the roof deck.
- U_{mr} = The thermal transmittance of the metal building roof area.
- A_{mr} = Opaque metal building roof area.
- U_{ra} = The thermal transmittance of the roof over attic and other roof area.
- A_{ra} = Opaque roof over attic and other roof area.
- U_{mw} = The thermal transmittance of the opaque mass wall area.
- A_{mw} = Opaque mass wall area (not including opaque doors).
- U_{mbw} = The thermal transmittance of the opaque metal building wall area.
- A_{mbw} = Opaque metal building wall area (not including opaque doors).
- U_{sfw} = The thermal transmittance of the opaque steel framed wall area.
- A_{sfw} = Opaque steel framed wall area (not including opaque doors).
- U_{wfw} = The thermal transmittance of the opaque wood framed and other wall area.
- A_{wfw} = Opaque wood framed and other wall area (not including opaque doors).
- U_{fm} = The thermal transmittance of the mass floor over unconditioned space area.
- A_{fm} = Mass floor area over unconditioned space.
- U_{fj} = The thermal transmittance of the joist floor over unconditioned space area.
- A_{fj} = Joist floor area over unconditioned space.
- F_s = Slab-on-grade floor component F-factor.
- P_s = Linear feet of slab-on-grade floor perimeter.
- F_{sr} = Radiant floor component F-factor.
- P_{sr} = Lineal feet of radiant floor perimeter.
- U_{ds} = The thermal transmittance value of the opaque swinging door area.
- A_{ds} = Opaque swinging door area.
- U_{dr} = The thermal transmittance value of the opaque roll-up or sliding door area.
- A_{dr} = Opaque roll-up or sliding door area.

Replaces Page CE-28

- U_{vg} = The thermal transmittance of the vertical fenestration area with nonmetal framing.*
- A_{vg} = Vertical fenestration area with nonmetal framing.*
- U_{vgmf} = The thermal transmittance of the vertical fenestration area with fixed metal framing.*
- A_{vgmf} = Vertical fenestration area with fixed metal framing.*
- U_{vgmo} = The thermal transmittance of the vertical fenestration area with operable metal framing.*
- A_{vgmo} = Vertical fenestration area with operable metal framing.*
- U_{vgd} = The thermal transmittance of the vertical fenestration area for entrance doors.*
- A_{vgd} = Vertical fenestration area for entrance doors.*
- U_{og} = The thermal transmittance for the skylights.
- A_{og} = Skylight area.

NOTE: Where more than one type of wall, window, roof/ceiling, door and skylight is used, the U and A terms for those items shall be expanded into subelements as:

$$U_{mw1}A_{mw1} + U_{mw2}A_{mw2} + U_{sfw1}A_{sfw1} + \dots \text{etc.}$$

***NOTE:** The vertical fenestration area does not include opaque doors and opaque spandrel panels.

EQUATION C402-3 TARGET SHGCA_T

$$SHGCA_t = SHGC_{ogt}(A_{ogort}) + SHGC_{vgt}(A_{ogt} + A_{vgt} + A_{vgmt} + A_{vgmot} + A_{vgdt})$$

Where:

$SHGCA_t$ = The target combined solar heat gain of the target fenestration area.

$SHGC_{ogt}$ = The solar heat gain coefficient for skylight fenestration found in Table C402.3 and A_{ogt} as defined in Equation C402-1.

$SHGC_t$ = The solar heat gain coefficient for fenestration found in Table C402.3 which corresponds to the proposed total fenestration area as a percent of gross exterior wall area, and A_{vgt} , A_{vgmt} , A_{vgmot} and A_{vgdt} are defined under Equation C402-1.

EQUATION C402-4 PROPOSED SHGCA_P

$$SHGCA_p = SHGC_{og}A_{og} + SHGC_{vg}A_{vg}$$

Where:

$SHGCA_t$ = The combined proposed solar heat gain of the proposed fenestration area.

$SHGC_{og}$ = The solar heat gain coefficient of the skylights.

A_{og} = The skylight area.

$SHGC_{vg}$ = The solar heat gain coefficient of the vertical fenestration.

A_{vg} = The vertical fenestration area.

NOTE: The vertical fenestration area does not include opaque doors and opaque spandrel panels.

**TABLE C402.2
OPAQUE THERMAL ENVELOPE REQUIREMENTS^{a, f}**

CLIMATE ZONE	5 AND MARINE 4		6	
	All Other	Group R	All Other	Group R
Roofs				
Insulation entirely above deck	R-30ci	R-38ci	R-30ci	R-38ci
Metal buildings (with R-3.5 thermal blocks) ^{a, b}	R-25 + R-11 LS	R-25 + R-11 LS	R-25 + R-11 LS	R-30 + R-11 LS
Attic and other	R-49	R-49	R-49	R-49
Walls, Above Grade				
Mass ^c	R-9.5ci	R-13.3ci	R-11.4ci	R-15.2ci
Metal building	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-19 + R-16ci
Steel framed	R-13 + R-10ci	R-19 + R-8.5ci	R-13 + R-12.5ci	R-19 + R-14ci
Wood framed and other	R-21 int	R-21 int	R-13 + R-7.5ci or R-20 + R-3.8ci	R-21 + R-5ci
Walls, Below Grade				
Below-grade wall ^d	Same as above grade			
Floors				
Mass	R-30ci	R-30ci	R-30ci	R-30ci
Joist/framing	R-30 ^e	R-30 ^e	R-38 ^e	R-38 ^e
Slab-on-Grade Floors				
Unheated slabs	R-10 for 24" below	R-10 for 24" below	R-10 for 48" below	R-15 for 48" below
Heated slabs ^d	R-10 perimeter & under entire slab			
Opaque Doors				
Swinging	U-0.37	U-0.37	U-0.37	U-0.37
Roll-up or sliding	R-4.75	R-4.75	R-4.75	R-4.75

For SI: 1 inch = 25.4 mm. ci = Continuous insulation. NR = No requirement.

LS = Liner system--A continuous membrane installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the membrane between the purlins.

- a. Assembly descriptions can be found in Chapter 2 and Appendix A.
- b. Where using R-value compliance method, a thermal spacer block shall be provided, otherwise use the U-factor compliance method in Table C402.1.2.
- c. **Exception:** Integral insulated concrete block walls complying with ASTM C90 with all cores filled and meeting both of the following:
 1. At least 50 percent of cores must be filled with vermiculite or equivalent fill insulation; and
 2. The building thermal envelope encloses one or more of the following uses: Warehouse (storage and retail), gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and waste water treatment facility, storage facility, storage area, motor vehicle service facility. Where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception and must comply with the appropriate mass wall R-value from Table C402.2 or U-factor from Table C402.1.2.

Replaces Page CE-30

- d. Where heated slabs are below grade, below-grade walls shall comply with the exterior insulation requirements for heated slabs.
- e. Steel floor joist systems shall be insulated to R-38 .+ R-10ci.
- f. For roof, wall or floor assemblies where the proposed assembly would not be continuous insulation, an alternate nominal R-value compliance options for assemblies with isolated metal penetrations of otherwise continuous insulation is:

Assemblies with continuous insulation (see definition)	Alternate option for assemblies with metal penetrations, greater than 0.04% but less than 0.08%
R-11.4ci	R-14.3 <u>ci</u>
R-13.3ci	R-16.6 <u>ci</u>
R-15.2ci	R-19.0 <u>ci</u>
R-30ci	R-38 <u>ci</u>
R-38ci	R-48 <u>ci</u>
R-13 .+ R-7.5ci	R-13 .+ R-9.4 <u>ci</u>
R-13 .+ R-10ci	R-13 .+ R-12.5 <u>ci</u>
R-13 .+ R-12.5ci	R-13 .+ R-15.6 <u>ci</u>
R-13 .+ R-13ci	R-13 .+ R-16.3 <u>ci</u>
R-19 .+ R-8.5ci	R-19 .+ R-10.6 <u>ci</u>
R-19 .+ R-14ci	R-19 .+ R-17.5 <u>ci</u>
R-19 .+ R-16ci	R-19 .+ R-20 <u>ci</u>
R-20 .+ R-3.8ci	R-20 .+ R-4.8 <u>ci</u>
R-21 .+ R-5ci	R-21 .+ R-6.3 <u>ci</u>

This alternate nominal R-value compliance option is allowed for projects complying with all of the following:

1. The ratio of the cross-sectional area, as measured in the plane of the surface, of metal penetrations of otherwise continuous insulation to the opaque surface area of the assembly is greater than 0.0004 (0.04%), but less than 0.0008 (0.08%).
2. The metal penetrations of otherwise continuous insulation are isolated or discontinuous (e.g., brick ties or other discontinuous metal attachments, offset brackets supporting shelf angles that allow insulation to go between the shelf angle and the primary portions of the wall structure). No continuous metal elements (e.g., metal studs, z-girts, z-channels, shelf angles) penetrate the otherwise continuous portion of the insulation.
3. Building permit drawings shall contain details showing the locations and dimensions of all the metal penetrations (e.g., brick ties or other discontinuous metal attachments, offset brackets, etc.) of otherwise continuous insulation. In addition, calculations shall be provided showing the ratio of the cross-sectional area of metal penetrations of otherwise continuous insulation to the overall opaque wall area.

For other cases where the proposed assembly is not continuous insulation, see Section C402.1.2 for determination of U-factors for assemblies that include metal other than screws and nails.

C402.2.1 Roof assembly. The minimum thermal resistance (*R*-value) of the insulating material installed either between the roof framing or continuously on the roof assembly shall be as specified in Table C402.2, based on construction materials used in the roof assembly. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.

Exceptions:

1. Continuously insulated roof assemblies where the thickness of insulation varies 1 inch (25 mm) or less and where the area-weighted *U*-factor is equivalent to the same assembly with the *R*-value specified in Table C402.2.
2. Unit skylight curbs included as a component of an NFRC 100 rated assembly shall not be required to be insulated.

Insulation installed on a suspended ceiling with removable ceiling tiles shall not be considered part of the minimum thermal resistance of the roof insulation.

C402.2.1.1 Roof solar reflectance and thermal emittance. Low-sloped roofs, with a slope less than 2 units vertical in 12 horizontal, directly above cooled *conditioned spaces* in Climate Zones 1, 2, and 3 shall comply with one or more of the options in Table C402.2.1.1.

Exceptions: The following roofs and portions of roofs are exempt from the requirements in Table C402.2.1.1:

1. Portions of roofs that include or are covered by:
 - 1.1. Photovoltaic systems or components.
 - 1.2. Solar air or water heating systems or components.
 - 1.3. Roof gardens or landscaped roofs.
 - 1.4. Above-roof decks or walkways.
 - 1.5. Skylights.
 - 1.6. HVAC systems, components, and other opaque objects mounted above the roof.
2. Portions of roofs shaded during the peak sun angle on the summer solstice by permanent features of the building, or by permanent features of adjacent buildings.
3. Portions of roofs that are ballasted with a minimum stone ballast of 17 pounds per square foot (psf) (74 kg/m²) or 23 psf (117 kg/m²) pavers.
4. Roofs where a minimum of 75 percent of the roof area meets a minimum of one of the exceptions above.

TABLE C402.2.1.1 REFLECTANCE AND EMITTANCE OPTIONS^a

Three-year aged solar reflectance ^b of 0.55 and three-year aged thermal emittance ^c of 0.75
Initial solar reflectance ^b of 0.70 and initial thermal emittance ^c of 0.75
Three-year-aged solar reflectance index ^d of 64 initial solar reflectance index ^d of 82

- a. The use of area-weighted averages to meet these requirements shall be permitted. Materials lacking initial tested values for either solar reflectance or thermal emittance, shall be assigned both an initial solar reflectance of 0.10 and an initial thermal emittance of 0.90. Materials lacking three-year aged tested values for either solar reflectance or thermal emittance shall be assigned both a three-year aged solar reflectance of 0.10 and a three-year aged thermal emittance of 0.90.
- b. Solar reflectance tested in accordance with ASTM C 1549, ASTM E 903 or ASTM E 1918.
- c. Thermal emittance tested in accordance with ASTM C 1371 or ASTM E 408.
- d. Solar reflectance index (SRI) shall be determined in accordance with ASTM E 1980 using a convection coefficient of 2.1 Btu/h x ft² x °F (12W/m² x K). Calculation of aged SRI shall be based on aged tested values of solar reflectance and thermal emittance. Calculation of initial SRI shall be based on initial tested values of solar reflectance and thermal emittance.

C402.2.2 Classification of walls. Walls associated with the building envelope shall be classified in accordance with Section C202.

C402.2.3 Thermal resistance of above-grade walls. The minimum thermal resistance (*R*-value) of the insulating materials installed in the wall cavity between the framing members and continuously on the walls shall be as specified in Table C402.2, based on framing type and construction materials used in the wall assembly. The *R*-value of integral insulation installed in concrete masonry units (CMU) shall not be used in determining compliance with Table C402.2.

"Mass walls" shall include walls weighing not less than:

1. 35 psf (170 kg/m²) of wall surface area; or
2. 25 psf (120 kg/m²) of wall surface area if the material weight is not more than 120 pounds per cubic foot (pcf) (1,900 kg/m³).

C402.2.4 Thermal resistance of below-grade walls. The minimum thermal resistance (*R*-value) of the insulating material installed in, or continuously on, the below-grade walls shall be as specified in Table C402.2.

C402.2.5 Floors over outdoor air or unconditioned space. The minimum thermal resistance (*R*-value) of the insulating material installed either between the floor framing or continuously on the floor assembly shall be as specified in Table C402.2, based on construction materials used in the floor assembly.

"Mass floors" shall include floors weighing not less than:

1. 35 psf (170 kg/m²) of floor surface area; or
2. 25 psf (120 kg/m²) of floor surface area if the material weight is not more than 120 pcf (1,900 kg/m³).

C402.2.6 Slabs on grade. Where the slab on grade is in contact with the ground, the minimum thermal resistance (*R*-value) of the insulation around the perimeter of unheated or heated slab-on-grade floors shall be as specified in Table C402.2. The insulation shall be placed on the outside of the foundation or on the inside of the foundation wall. The insulation shall extend downward from the top of the slab for a minimum distance as shown in the table or to the top of the footing, whichever is less, or downward to at least the bottom of the slab and then horizontally to the interior or exterior for the total distance shown in the table. Insulation extending away from the building shall be protected by pavement or by a minimum of 10 inches (254 mm) of soil.

Exception: Where the slab-on-grade floor is greater than 24 inches (61 mm) below the finished exterior grade, perimeter insulation is not required.

C402.2.7 Opaque doors. Opaque doors (doors having less than 50 percent glass area) shall meet the applicable requirements for doors as specified in Table C402.2 and be considered as part of the gross area of above-grade walls that are part of the building envelope.

C402.2.8 Insulation of radiant heating systems. Radiant panels, and associated U-bends and headers, designed for sensible heating of an indoor space through heat transfer from the thermally effective panel surfaces to the occupants or indoor space by thermal radiation and natural convection and the bottom surfaces of floor structures incorporating radiant heating shall be insulated with a minimum of R-3.5 (0.62 m²/K × W).

C402.3 Fenestration (Prescriptive). Fenestration shall comply with Table C402.3. Automatic daylighting controls specified by this section shall comply with Section C405.2.2.3.2.

C402.3.1 Maximum area. The vertical fenestration area (not including opaque doors and opaque spandrel panels) shall not exceed 30 percent of the gross above-grade wall area. The skylight area shall not exceed 3 percent of the gross roof area.

**TABLE C402.3
BUILDING ENVELOPE REQUIREMENTS -
FENESTRATION**

CLIMATE ZONE	5 AND MARINE 4	6
Vertical Fenestration		
U-factor		
Nonmetal framing (all) ^a	0.30	0.30
Metal framing (fixed) ^b	0.38	0.36
Metal framing (operable) ^c	0.40	0.40
Metal framing (entrance doors) ^d	0.60	0.60
SHGC		
SHGC	0.40	0.40
Skylights		
U-factor	0.50	0.50
SHGC	0.35	0.35

NR = No requirement.

- a. "Nonmetal framing" includes framing materials other than metal, with or without metal reinforcing or cladding.
- b. "Metal framing" includes metal framing, with or without thermal break. "Fixed" includes curtain wall, storefront, picture windows, and other fixed windows.
- c. "Metal framing" includes metal framing, with or without thermal break. "Operable" includes openable fenestration products other than "entrance doors."
- d. "Metal framing" includes metal framing, with or without thermal break. "Entrance door" includes glazed swinging entrance doors. Other doors which are not entrance doors, including sliding glass doors, are considered "operable."

C402.3.1.1 Increased vertical fenestration area with daylighting controls. In Climate Zones 1 through 6, a maximum of 40 percent of the gross above-grade wall area shall be permitted to be vertical fenestration, provided:

1. No less than 50 percent of the conditioned floor area is within a daylight zone;
2. Automatic daylighting controls are installed in daylight zones; and
3. Visible transmittance (VT) of vertical fenestration is greater than or equal to 1.1 times solar heat gain coefficient (SHGC).

Exception: Fenestration that is outside the scope of NFRC 200 is not required to comply with Item 3.

C402.3.1.2 Increased skylight area with daylighting controls. The skylight area shall be permitted to be a maximum of 5 percent of the roof area provided automatic daylighting controls are installed in daylight zones under skylights.

C402.3.1.3 Increased vertical fenestration area with high-performance fenestration. The vertical fenestration area (not including opaque doors and opaque spandrel panels) is permitted to exceed 30% but shall not exceed 40% of the gross above grade wall area, for the purpose of prescriptive compliance with Section C402.1.2 or for the Target UA calculation in Equation C402-1, provided that each of the following conditions are met:

1. The vertical fenestration shall have the following U-factors:
 - a. Non-metal framing (all) = 0.28
 - b. Metal framing (fixed) = 0.34
 - c. Metal framing (operable) = 0.36
 - d. Metal framing (entrance doors) = 0.60
2. The SHGC of the vertical fenestration shall be less than or equal to 0.35, adjusted for projection factor in compliance with C402.3.3.1.

The compliance path described in this section is not permitted to be used for the Total Building Performance compliance path in Section C407.

C402.3.2 Minimum skylight fenestration area. For single story buildings only, in an enclosed space greater than 10,000 square feet (929 m²), directly under a roof with ceiling heights greater than 15 feet (4572 mm), and used as an office, lobby, atrium, concourse, corridor, gymnasium/exercise center, convention center, automotive service, manufacturing, nonrefrigerated warehouse, retail store, distribution/sorting area, transportation, or workshop, the total daylight zone under skylights shall be not less than half the floor area and shall provide a minimum skylight area to daylight zone under skylights of either:

1. Not less than 3 percent with a skylight VT of at least 0.40; or
2. Provide a minimum skylight effective aperture of at least 1 percent determined in accordance with Equation C4-1.

$$\text{Skylight Effective Aperture} = \frac{0.85 \times \text{Skylight Area} \times \text{Skylight VT} \times \text{WF}}{\text{Daylight zone under skylight}}$$

(Equation C4-1)

where:

Skylight area	=	Total fenestration area of skylights.
Skylight VT	=	Area weighted average visible transmittance of skylights.
WF	=	Area weighted average well factor, where well factor is 0.9 if light well depth is less than 2 feet (610 mm), or 0.7 if light well depth is 2 feet (610 mm) or greater.
Light well depth	=	Measure vertically from the underside of the lowest point of the skylight glazing to the ceiling plane under the skylight.

C402.3.2.1 Lighting controls in daylight zones under skylights. All lighting in the daylight zone shall be controlled by automatic daylighting controls that comply with Section C405.2.2.3.2.

Exception: Skylights above daylight zones of enclosed spaces are not required in:

1. Buildings in Climate Zones 6 through 8.
2. Spaces where the designed *general lighting* power densities are less than 0.5 W/ft² (5.4 W/m²).
3. Areas where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed area for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m.
4. Spaces where the daylight zone under rooftop monitors is greater than 50 percent of the enclosed space floor area.

C402.3.2.2 Haze factor. Skylights in office, storage, automotive service, manufacturing, nonrefrigerated warehouse, retail store, and distribution/sorting area spaces shall have a glazing material or diffuser with a measured haze factor greater than 90 percent when tested in accordance with ASTM D 1003.

Exception: Skylights designed to exclude direct sunlight entering the occupied space by the use of fixed or automated baffles, or the geometry of skylight and light well need not comply with Section C402.3.2.2.

C402.3.3 Maximum U-factor and SHGC. For vertical fenestration, the maximum U-factor and solar heat gain coefficient (SHGC) shall be as specified in Table C402.3, based on the window projection factor. For skylights, the maximum U-factor and solar heat gain coefficient (SHGC) shall be as specified in Table C402.3.

5. A narrative of how each system is intended to operate, including recommended setpoints. Sequence of operation is not acceptable for this requirement.

C408.1.3.3 System balancing report. A written report describing the activities and measurements completed in accordance with Section C408.2.2.

C408.1.3.4 Final commissioning report. A report of test procedures and results identified as "Final Commissioning Report" shall be delivered to the building owner and shall include:

1. Results of functional performance tests.
2. Disposition of deficiencies found during testing, including details of corrective measures used or proposed.
3. Functional performance test procedures used during the commissioning process including measurable criteria for test acceptance, provided herein for repeatability.

Exception: Deferred tests which cannot be performed at the time of report preparation due to climatic conditions.

C408.1.4 Systems operation training. Training of the maintenance staff for equipment included in the manuals required by Section C408.1.3.2 shall include at a minimum:

1. Review of systems documentation.
2. Hands-on demonstration of all normal maintenance procedures, normal operating modes, and all emergency shutdown and start-up procedures.
3. Training completion report.

C408.2 Mechanical systems commissioning and completion requirements. Mechanical equipment and controls shall comply with Section C408.2.

Construction document notes shall clearly indicate provisions for *commissioning* and completion requirements in accordance with this section and are permitted to refer to specifications for further requirements.

Exception: Systems which (a) qualify as simple systems using the criteria in Section C403.3, (b) are not required to have an economizer per Section C403.3.1, and (c) where the building total mechanical equipment capacity is less than 480,000 Btu/h (140,690 W) cooling capacity and 600,000 Btu/h (175,860 W) heating capacity.

C408.2.1 Reserved.

C408.2.2 Systems adjusting and balancing. HVAC systems shall be balanced in accordance with generally

accepted engineering standards. Air and water flow rates shall be measured and adjusted to deliver final flow rates within the tolerances provided in the product specifications. Test and balance activities shall include air system and hydronic system balancing.

C408.2.2.1 Air systems balancing. Each supply air outlet and *zone* terminal device shall be equipped with means for air balancing in accordance with the requirements of Chapter 6 of the *International Mechanical Code*. Discharge dampers are prohibited on constant volume fans and variable volume fans with motors 10 hp (18.6 kW) and larger. Air systems shall be balanced in a manner to first minimize throttling losses then, for fans with system power of greater than 1 hp (0.74 kW), fan speed shall be adjusted to meet design flow conditions.

Exception: Fans with fan motors of 1 hp (0.74 kW) or less.

C408.2.2.2 Hydronic systems balancing. Individual hydronic heating and cooling coils shall be equipped with means for balancing and measuring flow. Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses, then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions. Each hydronic system shall have either the capability to measure pressure across the pump, or test ports at each side of each pump.

Exceptions:

1. Pumps with pump motors of 5 hp (3.7 kW) or less.
2. Where throttling results in no greater than five percent of the nameplate horsepower draw above that required if the impeller were trimmed.

C408.2.3 Functional performance testing. Functional performance testing specified in Sections C408.2.3.1 through C408.2.3.3 shall be conducted. Written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. At a minimum, testing shall affirm operation during actual or simulated winter and summer design conditions and during full outside air conditions.

C408.2.3.1 Equipment. Equipment functional performance testing shall demonstrate the installation and operation of components, systems, and system-to-system interfacing relationships in

accordance with approved plans and specifications such that operation, function, and maintenance serviceability for each of the commissioned systems is confirmed. Testing shall include all modes and *sequence of operation*, including under full-load, part-load and the following emergency conditions:

1. All modes as described in the *sequence of operation*;
2. Redundant or *automatic* back-up mode;
3. Performance of alarms; and
4. Mode of operation upon a loss of power and restoration of power.

→ **C408.2.3.2 Controls.** HVAC control systems shall be tested to document that control devices, components, equipment, and systems are calibrated, adjusted and operate in accordance with approved plans and specifications. Sequences of operation shall be functionally tested to document they operate in accordance with *approved* plans and specifications.

C408.2.3.3 Economizers. Air economizers shall undergo a functional test to determine that they operate in accordance with manufacturer's specifications.

→ **C408.3 Lighting system functional testing.** Controls for automatic lighting systems shall comply with Section C408.3.1.

Exception: Lighting systems in buildings where the total installed lighting load is less than 20kW and less than 10 kW of lighting is controlled by occupancy sensors or automatic daylighting controls.

C408.3.1 Functional testing. Testing shall ensure that control hardware and software are calibrated, adjusted, programmed and in proper working condition in accordance with the construction documents and manufacturer's installation instructions. Written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. At a minimum, testing shall affirm operation during normally occupied daylight conditions. The construction documents shall state the party who will conduct the required functional testing.

Where occupant sensors, time switches, programmable schedule controls, photosensors or daylighting controls are installed, the following procedures shall be performed:

1. Confirm that the placement, sensitivity and time-out adjustments for occupant sensors yield acceptable performance.
2. Confirm that the time switches and programmable schedule controls are

programmed to turn the lights off.

3. Confirm that the placement and sensitivity adjustments for photosensor controls reduce electric light based on the amount of usable daylight in the space as specified.

C408.4 Service water heating systems commissioning and completion requirements. Service water heating equipment and controls shall comply with Section C408.4. Construction document notes shall clearly indicate provisions for *commissioning* and completion requirements in accordance with this section and are permitted to refer to specifications for further requirements.

Exception: The following systems are exempt from the commissioning requirements:

1. Service water heating systems in buildings where the largest service water heating system capacity is less than 200,000 Btu/h (58,562 W) and where there are no pools or in-ground permanently installed spas.

C408.4.1 Functional performance testing. Functional performance testing specified in Sections C408.4.1.1 through C408.4.1.3 shall be conducted. Written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. At a minimum, testing shall affirm operation with the system under 50 percent water heating load.

C408.4.1.1 Equipment. Equipment functional performance testing shall demonstrate the installation and operation of components, systems, and system-to-system interfacing relationships in accordance with approved plans and specifications such that operation, function, and maintenance serviceability for each of the commissioned systems is confirmed. Testing shall include all modes and *sequence of operation*, including under full-load, part-load and the following emergency conditions:

1. Redundant or *automatic* back-up mode;
2. Performance of alarms; and
3. Mode of operation upon a loss of power and restoration of power.

C408.4.1.2 Controls. Service water heating controls shall be tested to document that control devices, components, equipment, and systems are calibrated, adjusted and operate in accordance with approved plans and specifications. Sequences of operation shall be functionally tested to document they operate in accordance with *approved* plans and specifications.

Replaces Page CE-96